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(54) Vacuum type wafer holder.

(57) A wafer holding device of vacuum attraction type, includes a structural member (1) having a protrusion (2) for supporting a wafer; and elastic members (3') made of a material having an elasticity modulus smaller than that of the wafer and that of the structural member, the elastic members being distributed on a wafer attraction plane of the structural member.

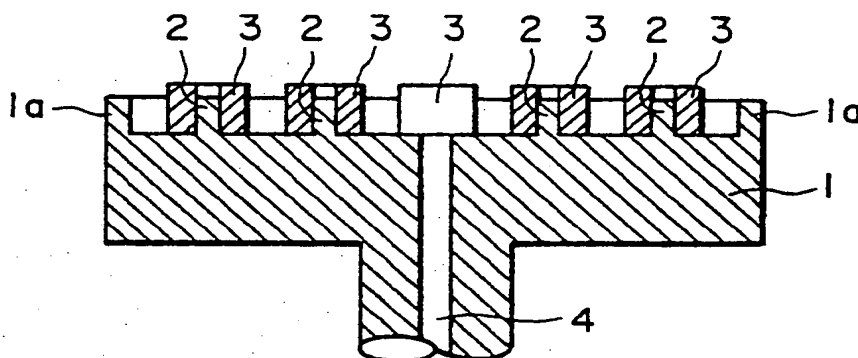


FIG. 2

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## FIELD OF THE INVENTION AND RELATED ART

This invention relates to a vacuum chuck and, more particularly, to a vacuum attraction type wafer holding device usable in a semiconductor device manufacturing exposure apparatus, for holding a wafer by attracting a bottom face of the wafer through vacuum attraction.

In the field of semiconductor device manufacturing apparatuses, for transfer of a semiconductor device pattern of a mask onto a semiconductor wafer, the wafer is held by a wafer holding device. A typical example is disclosed in Japanese Published Patent Application No. 1-14703 wherein a wafer is held by attracting the bottom face thereof through vacuum attraction.

Generally, when a wafer is held by a wafer holding device and if there is a large contact heat resistance at the contact surface between the wafer and the holding device, the heat generated in the wafer by application of exposure energy, for the mask pattern transfer to the wafer, is not easily transmitted from the wafer to the holding device. This causes temperature rise in the wafer and thermal deformation of it and, thus, leads to degradation of the pattern transfer precision. Particularly, in vacuum attraction type wafer holding devices, since substantially no gas remains in the space between the wafer and the holding device except the contact surface therebetween, there occurs a considerable temperature rise in the wafer. Thus, the degradation of the pattern transfer precision is notable.

When a vacuum attraction type wafer holding device is used in a proximity type exposure apparatus wherein a mask and a wafer are placed with a small clearance of about several ten microns, if there is a large contact heat resistance, the temperature rise in the wafer causes a temperature rise in the mask. If this occurs, thermal distortion is produced also in the mask and, therefore, the pattern transfer precision is degraded considerably.

Conventionally, a vacuum attraction type wafer holding device comprises a main structural member (table) with a wafer contact surface finished to provide a good flatness for ensuring flatness of a wafer as the same is attracted to the attracting surface. The main structural member is made of a rigid material with a large elasticity modulus for flatness correction, for correcting any warp of the attracted wafer. Thus, the contact heat resistance of such a main structural member may be small.

## SUMMARY OF THE INVENTION

In this type of wafer holding device, however, even the finished wafer contact surface has small surface irregularity or waviness. Also, the bottom face of each wafer has small surface irregularity or waviness.

Therefore, when the bottom face of the wafer is attracted to the wafer contact surface, the actual area of the wafer contact surface is smaller than the apparent area of the same. Thus, the contact heat resistance is not so small and it is not easy to completely prevent degradation of the pattern transfer precision.

It is accordingly a primary object of the present invention to provide a wafer holding device, particularly of vacuum attraction type, with which the contact heat resistance can be made small.

It is another object of the present invention to provide a wafer holding device, particularly of vacuum attraction type, with which enhanced pattern transfer precision is assured.

In accordance with an aspect of the present invention, a wafer holding device of vacuum attraction type includes a main structural member having a wafer attraction plane in which elastic members of an elasticity modulus smaller than that of a wafer and that of the main structural member are distributed. In a preferred form, each elastic member projects beyond wafer supporting protrusions also distributed in the wafer attraction plane when no wafer is attracted thereto.

In a wafer holding device of the present invention, a wafer attracted thereto through vacuum attraction is held while being in contact with the elastic members. Since these elastic members have an elasticity modulus smaller than that of the wafer, even if the bottom face of the wafer has small surface irregularity or waviness, the contact surface of each elastic member can deform in compliance with the surface irregularity or waviness. As a result, a small contact heat resistance at the contact surface is ensured.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is top plan view of a wafer holding device of vacuum attraction type according to a first embodiment of the present invention.

Figure 2 is a sectional view taken on a line A - A' in Figure 1.

Figure 3 is an enlarged view showing a protrusion and an associated elastic member before a wafer is attracted thereto.

Figure 4 is an enlarged view showing the protrusion and the elastic member of Figure 3, after the wafer is attracted thereto.

Figure 5 is a top plan view of a wafer holding device of vacuum attraction type according to a second embodiment of the present invention.

Figure 6 is a sectional view taken on line A - A' in Figure 5.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will now be explained in conjunction with the attached drawings.

Referring first to Figures 1 - 4, a first embodiment of the present invention will now be explained.

Wafer holding device of vacuum attraction type according to this embodiment includes a main structural member 1 which is made of a rigid material such as stainless steel or ceramics, for example, having a large elasticity modulus, for correction of warp of a semiconductor wafer to be attracted thereto (see Figure 3). The main structural member 1 has an outer circumferential wall 1a formed as a unit therewith. On the upper surface of the main structural member as encircled by the outer circumferential wall 1a, which surface is to be opposed a wafer to be attracted, there are provided plural protrusions 2, of a number of twelve in this example, each having a pin-like shape. These protrusions 2 have the same height (level) and are formed as a unit with the main structural member 1. Also, these protrusions are disposed with good symmetry.

Each projection 2 has an elastic member 3 which surrounds the associated projection. The elastic members 3 have the same height (level). The main structural member 1 has a vacuum port 4 formed therein for communicating the central portion of the upper surface of the main structural member with a vacuum source, not shown.

Each elastic member 3 is made of a material having an elasticity modulus smaller than that of the main structural member 1 and that of a wafer 5 to be attracted. Examples of usable material are: synthetic resin such as polypropylene, polyester, nylon, silicon rubber, synthetic rubber and the like. Further, a metal such as indium or the like which easily cause plastic deformation may be used, if within the range of elastic deformation.

As seen in Figure 3, the elastic member 3 has a height  $D + d$  (mm) which is higher than the height  $D$  (mm) of the protrusion 2, by an amount  $d$  (mm). In other words, the elastic member 3 projects beyond the top of the protrusion 2 by  $d$  (mm). Each of the protrusion 2 and the elastic member 3 has a top surface (contact surface) having been finished to obtain a predetermined surface flatness, for the contact with an attracted wafer 5.

The wafer attracting operation will now be explained by reference to Figures 3 and 4.

Before start of wafer attracting operation, a semiconductor wafer 5 to be attracted is conveyed by means of a conveying hand (not shown) to a position such as shown in Figure 3 whereat the bottom face of the wafer 5 contacts the contact surface of the elastic member 3. After this, the vacuum port 4 is opened to the vacuum source (not shown) and the vacuum

attraction to the bottom face of the wafer 5 starts. Here, if the ambience pressure (e.g. atmospheric pressure) at the upper face side of the wafer 5 is  $T$  (Torr), then the gas in the space enclosed by the main structural member 1, the outer circumferential wall 1a and the wafer 5 is evacuated by the vacuum source until the pressure in that space (i.e. attraction pressure) becomes equal to  $t$  (Torr) which is zero (0), for example. Thus, a pressure difference of  $T - t$  (Torr) is produced between the top surface and the bottom surface of the wafer 5. As a result, if the wafer attraction area of the wafer holding device is  $S_w$ , then an attraction force of

$$(T - t)/760 \times 10^5 \times S_w \quad (\text{Pa}) \quad (1)$$

is applied to the wafer 5.

On the other hand, as the wafer is attracted toward the upper surface of the main structural member 1 by means of this attraction force, the elastic member 3 is contracted by an amount corresponding to the quantity of displacement of the wafer 5. As a result, a repulsive force of the elastic member 3 is applied to the bottom surface of the wafer 5 in proportion to the displacement of the wafer. Therefore, when the wafer 5 is displaced by an amount corresponding to the difference  $d$  (mm) (where  $d > 0$ ) between the height  $(D + d)$  (mm) of the elastic member 3 and the height  $(D)$  (mm) of the protrusion 2 and if the Young's modulus of the elastic member 3 is  $E$  (Pa) and the contact surface area between the wafer 5 and the elastic members 3 (total) is  $S_e$ , then the repulsive force  $F$  to be applied to the wafer 5 is expressed as:

$$F = E \times d / (D + d) \times S_e \quad (\text{Pa}) \quad (2)$$

It is seen therefrom that, in order to assure engagement of the bottom surface of the wafer 5 with the contact surface of the protrusion 2 against the repulsive force  $F$ , the level difference  $d$  (mm) should satisfy a relation (3) such as follows:

$$E \times d / (D + d) \times S_e < (T - t) / 760 \times 10^5 \times S_w \quad (3)$$

On the other hand, in order to retain a space for allowing contraction of the elastic member 3, between the wafer attraction area  $S_w$  and the contact surface area  $S_e$ , there should be a relation:

$$0 < d \leq (S_w - S_e) / S_e \times D \quad (4)$$

It follows that, if  $760 \cdot E \cdot S_e > (T - t) \cdot 10^5 \cdot S_w$ , the relation (3) is rewritten into a relation (5), below, and therefore if the level difference  $d$  is so set as to satisfy the relation (4) as well as the relation (5), the attracting operation can be performed without problem:

$$0 < d < [(T - t) \times 10^5] / [760 \cdot E \cdot S_e / S_w - (T - t) \times 10^5] \cdot D \quad (5)$$

If on the other hand  $760 \cdot E \cdot S_e \leq (T - t) \times 10^5$ , the attracting operation can be performed without problem provided that the level difference  $d$  is so set as to satisfy the relation (4).

After the attracting operation is completed in the manner described, the bottom face of the wafer 5 is vacuum attracted to and held by the wafer holding device, while being in contact to the contact surfaces of the protrusions 2 and the elastic members 3.

Although the contact surface of each protrusion 2 has been finished, it may have small surface irregularity or waviness. Also, the bottom face of the wafer 5 may have small surface irregularity or waviness. Therefore, usually it is not possible to attain small contact heat resistance at the contact surface of the protrusion 2.

Since, however, each elastic member 3 is made of a material having an elasticity modulus smaller than that of the wafer 5, the contact surface thereof can easily deform in compliance with the surface irregularity or waviness of the bottom face of the wafer 5. As a result, the contact heat resistance at the contact surface of the elastic member can be made very small.

Accordingly, when in this state an exposure energy is applied to the wafer 5 for lithographic pattern transfer to the wafer, for semiconductor device manufacture, any heat applied to or produced in the wafer can be easily transmitted to the main structural member 1 and, therefore, degradation of the pattern transfer precision due to heat generation can be prevented effectively.

This has been confirmed by the inventors of the subject application. Namely, the inventors prepared a wafer holding device wherein its main structural member was made of stainless steel and its elastic members were made of silicon rubber. The height D of the main structural member 1 was 1 (mm), and the height D + d of each elastic member 3 was 1.05 (mm), wherein the level difference d = 0.05 (mm). After a wafer having a relatively good surface flatness was attracted, the contact heat resistance R1 was measured. The result is that:

$$R1 = 1 \times 10^{-3} \quad (\text{K} \cdot \text{m}^2 / \text{W})$$

Also, the contact heat resistance R2 of a comparative example device without any elastic member was measured. The result is that:

$$R2 = 1 \times 10^{-2} \quad (\text{K} \cdot \text{m}^2 / \text{W})$$

It is seen therefrom that, in accordance with the present embodiment, the contact heat resistance can be reduced to one-tenth (1/10) of that of the conventional wafer holding device and also that the temperature rise in the wafer can be reduced to one-tenth. As a result, the pattern transfer precision can be improved significantly.

While in the present embodiment each protrusion has a columnar pin-like shape as illustrated in Figure 1, it is not limited to the disclosed form. Prismatic pin-like shape may be adopted, as an example.

Figures 5 and 6 show a wafer holding device of vacuum attraction type according to a second embodiment of the present invention.

In this embodiment, two concentrically disposed ring-like protrusions 12a are formed on the upper surface of a main structural member 11 as a unit therewith, the upper surface being encircled by an outer circumferential wall 11a. The two protrusions 12a are connected to each other by four protrusions 12b

which extend in directions inclined by 45 deg. as viewed in Figure 5 with good symmetry. The outer ring-like protrusion 12a is connected to the outer circumferential wall 11b by four protrusions 12c which extend in longitudinal and transverse directions as viewed in Figure 5 with good symmetry.

On the upper surface segments of the main structural member 11 as enclosed by the two ring-like projections 12a and the outer circumferential wall 11a, there are formed eight elastic members 13 each having a shape like a part of a ring. These elastic members 13 are disposed with good symmetry. Also, on the central portion of the upper surface of the main structural member 11, there is formed a circular elastic member 13. Further, the main structural member 11 has a number of vacuum ports 14 which are distributed in the upper surface of the main structural member with good symmetry.

In this embodiment, for allowing flatness correction of such a wafer as having a low surface flatness as compared with the wafer 5 as described with reference to the first embodiment, the level difference d is so set as to satisfy the following relation:

$$0 < d < [(T-t) \times 10^4] / [760 \cdot E \cdot \text{Se} / \text{Sw} - (T-t) \times 10^4] \cdot D \quad (6)$$

This ensures tight engagement of the bottom face of the wafer with the protrusions 12.

It has been confirmed by experiments that, for a Si wafer having a flatness of 10 (micron) per 30 (mm) square, a thickness of 0.6 (mm) and a diameter of 150 (mm), the flatness correction can be performed with a differential pressure not less than 100 (Torr). Therefore, in order to ensure flatness correction through a differential pressure not less than 100 (Torr) and thus to assure abutment of the wafer 5 against the protrusions 12 through a force not less than 100 (Torr), the relation (3) as discussed is rewritten as follows:

$$\text{Exd} / (D + d) \times \text{Se} + 100 / 760 \times 10^5 \times \text{Sw} < (T-t) / 760 \times 10^5 \times \text{Sw} \quad (3')$$

Accordingly, in this case, the level difference d may be determined to satisfy a relation (7), below, which can be derived from rewriting the relation (3'):

$$0 < d < [(T-t-100) \times 10^5] / [760 \cdot E \cdot \text{Se} / \text{Sw} - (T-t-100) \times 10^5] \cdot D \quad (7)$$

With this level difference, under a pressure difference not less than 100 (Torr), the bottom face of the wafer can be engaged with certainty to the contact surfaces of the protrusions 12a against the repulsive force F of the elastic members 13.

Generally, therefore, if sufficient flatness correction to a wafer is attainable with a differential pressure of T' (Torr), then in an ambience T > T' by setting the level difference d so as to satisfy the following relation:

$$0 < d < [(T-t-T') \times 10^5] / [760 \cdot E \cdot \text{Se} / \text{Sw} - (T-t-T') \times 10^5] \cdot D \quad (8)$$

it is possible to assure tight engagement of the bottom face of the wafer with the contact surface of the protrusion 12 and satisfactory flatness correction of the

wafer. It is to be noted here that it is not the second embodiment only, to which the relations (6) - (8) apply.

Also with the arrangement of the present embodiment, the contact heat resistance of the contact surface of the elastic member 13 with which an attracted wafer is to be held, can be made so small that enhanced pattern transfer precision is assured.

In the foregoing embodiments, the protrusions and the elastic members are disposed with good symmetry. However, they may be disposed asymmetrically. Since however a wafer usually has a circular shape, the symmetrical structure of elastic members can ensure better flatness precision of the wafer after it is attracted. Further, in the foregoing embodiment, each elastic member is formed integrally with an associated protrusion or protrusions, it may be provided separately.

While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the purposes of the improvements or the scope of the following claims.

#### Claims

1. A wafer holding device, comprising:
  - a structural member having a protrusion for supporting a wafer; and
  - elastic members made of a material having an elasticity modulus smaller than that of the wafer and that of the structural member, the elastic members being distributed on a wafer attraction plane of the structural member.
2. A device according to Claim 1, wherein, when the wafer is not attracted to the device, each elastic member projects beyond the protrusion.
3. A device according to Claim 1, wherein the protrusion includes a plurality of pins and wherein each elastic member surrounds corresponding one of the pins.
4. A device according to Claim 1, wherein the protrusion and the elastic members are disposed symmetrically.
5. A method of manufacture of semiconductor devices, comprising the steps of:
  - preparing a wafer holding device for holding a wafer through vacuum attraction, the holding device including a structural member with a protrusion and elastic members distributed on a wafer attraction plane of the holding device, wherein each elastic member is made of a material

having an elasticity modulus smaller than that of the protrusion;

placing the wafer on the wafer holding device so that it is held by the holding device; and

applying an exposure energy to the wafer held by the wafer holding device so that a pattern for manufacture of a semiconductor device is transferred to the wafer.

6. A method according to Claim 5, wherein, when the wafer is not attracted to the wafer holding device, the elastic member projects beyond the protrusion.

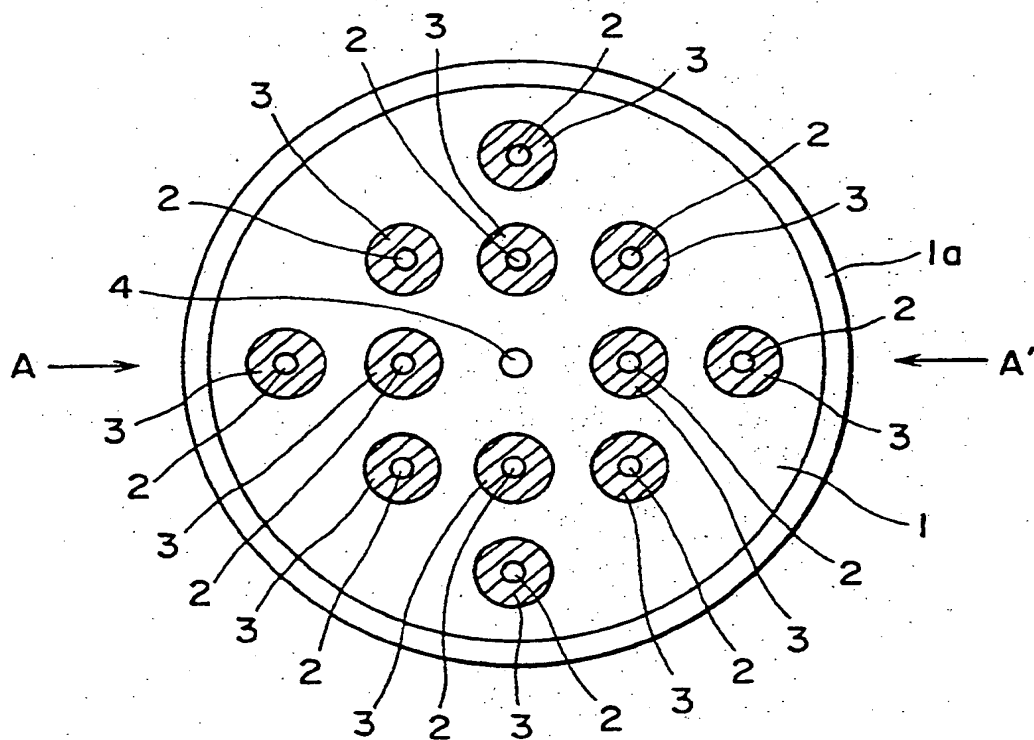


FIG. 1

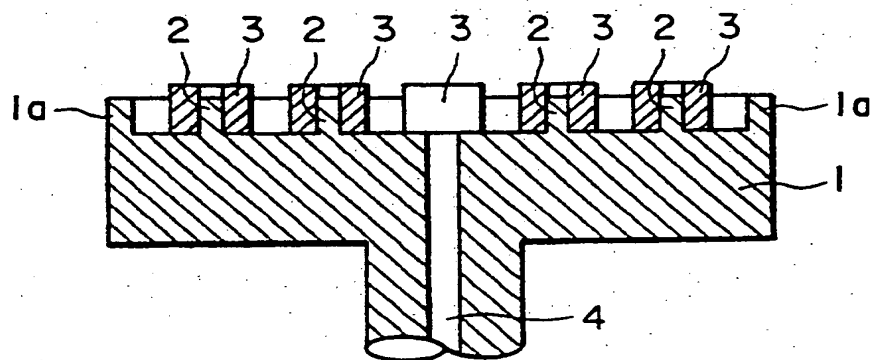


FIG. 2

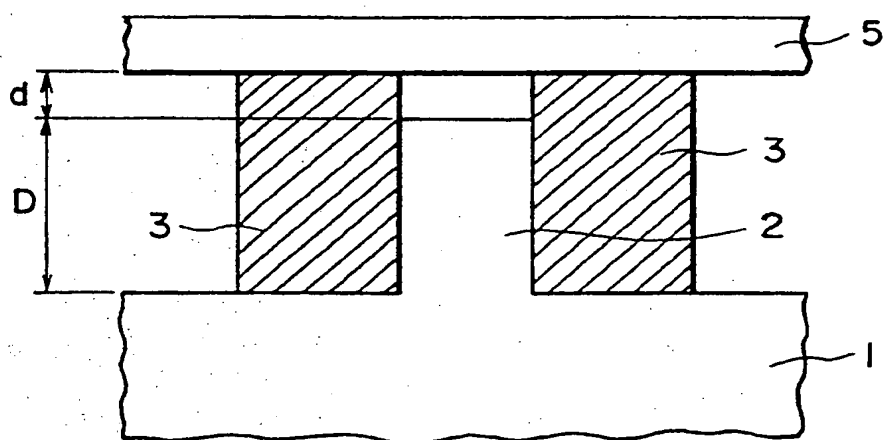


FIG. 3

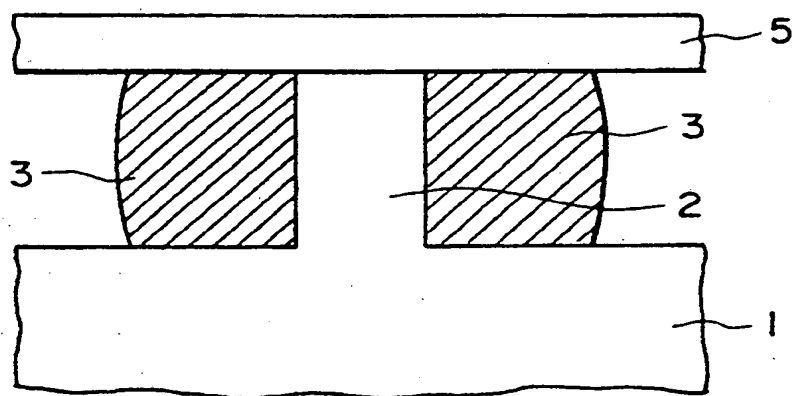


FIG. 4

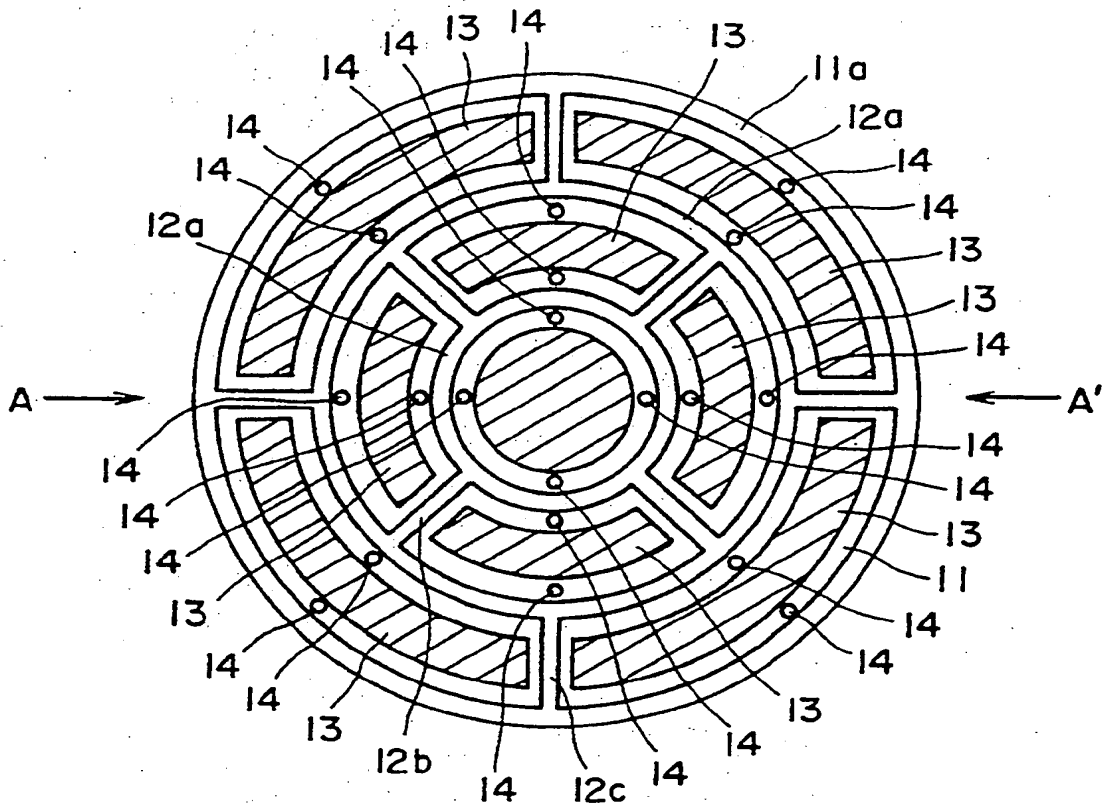


FIG. 5

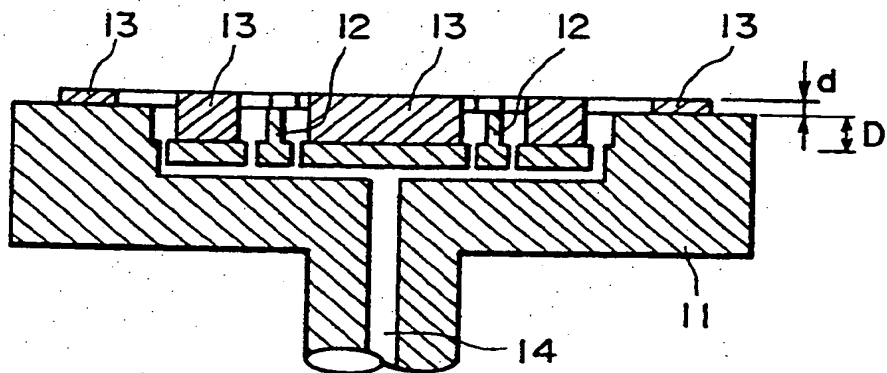


FIG. 6





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# EUROPEAN SEARCH REPORT

Application Number

EP 91 30 4027

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
X	PATENT ABSTRACTS OF JAPAN vol. 9, no. 56 (E-302) 12 March 1985, & JP-A-59 195826 (TOSHIBA K.K.) 07 November 1984, * the whole document *	1, 2, 4	H01L21/00 C23C14/50
Y	---	5, 6	
Y	EP-A-323902 (VARIAN ASSOCIATES INC.) * column 1, lines 1 - 36 * * column 1, line 52 - column 2, line 14 * * column 4, line 33 - column 5, line 33; figure 1A * * column 6, line 31 - column 7, line 25; figure 2 *	5, 6	
A	---	1	
X	EP-A-298564 (PHILIPS AND DU PONT OPTICAL COMPANY) * column 4, lines 29 - 44; figures 1-4 * * column 5, line 21 - column 6, line 32; figure 5 *	1, 2	
A	-----	3-6	TECHNICAL FIELDS SEARCHED (Int. CL.5)  H01L H01J C23C C30B H05K
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 26 JULY 1991	Examiner KLOPFENSTEIN P.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

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